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Ubiquitous RFID Network for Highway Monitoring and Management

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Abstract

A simplified approach for the implementation of ubiquitous RFID networks in a Highway Management System is presented. The technique aims at deploying tagging identification in transport statistical analysis. The RFID network architecture has been designed as part of an existing system to make it more cost effective with a higher reliability. The usefulness and the merits of this easy access and user friendly approach are identified and discussed.

Index Term – RFID, Ubiquitous Network, Highway Management

1. Introduction

RFID highway management system (HMS) is a system capable of generating comprehensive statistical data on vehicles. It operates a number of standard RFID readers in specific locations forming a multi reference system connected to a central database. The system provides information relating to the location of a certain vehicle at a certain time to the database. Together with existing highway-related systems such as CCTV cameras and speed detectors that can be linked to a highway digital map and a variety of highway-related data [1] may constitute a highly efficient monitoring system. The scope of this work focuses on Malaysian road management environment.

With the emergence of RFID based tags, it is now practicable to automatically collect information pertaining to any object with respect to location, time, transaction, etc [3]. Passive RFID tags require no batteries, and less or no maintenance. Instead, they may get power from the reader using either inductive coupling or electromagnetic capture.

Different applications may require interfaces, which are usually built for communication between the RFID application system and the tag, or between the application enterprise and a persistence data storage medium [5].

2. System Implementation

An RFID system consists of two major components; the reader including antenna, and the transponder, i.e. the tag as shown in figure 1. The tag is usually placed on the object to be identified or embedded in it. The object may be a road tax sticker or driving license, etc. Communication between the tag and the reader is via a well defined radio frequency link and a protocol. The protocol involves three parts, which must be transmitted.

- **Data** in both directions
- **Clock** signal from reader to tag
- **Energy** from reader to activate the tag.

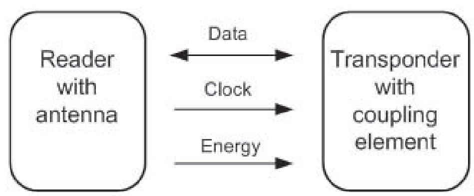

Figure 1: Basic RFID communication.

The tag employs either load modulation or electromagnetic backscatter at its antenna to send the identity and the data to the reader. The system can randomize the reply time so that it can query multiple tags simultaneously and minimize contention between their responses.

The RFID system can be enabled by the ubiquitous sensors, which are made as parts of the input devices in the HMS application. Extending the interface capabilities of the sensor is straightforward [3], by an active tag. A reader equipped with a GPS can write the reader's location into the tag along with the read time. This information may be saved as a tag reference table.

ID: <Location (l_n) > : < Time (t_n) >

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If the location and time are known, then any data from the tag captured within the roaming distance of the reader can be stored in the centralized database of the HMS. Statistical analysis can be done by processing the information stored in the centralized database. For example, the average speed, v_{avg} of vehicles along the highway can be computed as follows:

$$\left|v_{avg}\right|_{collection} = \left|\frac{l_{n+1} - l_n}{t_{n+1} - t_n}\right|_{collection}$$

l = reader's location
t = recorded time

The raw data read by the RFID reader accumulated in the HMS centralized database will be arranged in a database table. The detailed network database process will be elaborated in section 5. The computed statistical data in the HMS can be shared with other local authority databases through the secured structured network. The local authority such as Transport and Road Department and Police Department (Traffic unit) can benefit from the ability to access and monitor the statistics of HMS databases in application such as:

- Accident Scene Investigation
- Offence Prevention Management
- Merit Point Monitoring
- License and Road Tax Renewal

Those databases can only be managed and updated by the respective authority. However the data can be accessed and shared among the local authority within the secured RFID ubiquitous network topology.

3. RFID Ubiquitous Network Architecture

The RFID ubiquitous network architecture connects the local and enterprise network interfaces for comprehensive data management. The data management infrastructure must be in place to coordinate the transition of data between different networks that use different standards. RFID tag technology requires communications and data management infrastructure that must co-exist with other wireless communication technologies. The architecture must be scalable and independent of hardware. The idea is illustrated in figure 2.

The RFID reader is placed at a strategic location along the highway. The system can be developed to combined RFID and WLAN into an access point. In this architecture, the readers are connected to a secured wireless LAN. The RFID reader detects the moving RFID tag along the highway and updates the information in the HMS. This information has to be managed at a very fast rate. The ubiquitous structured network architecture smoothens the data coming from RFID reader and manages the data flow.

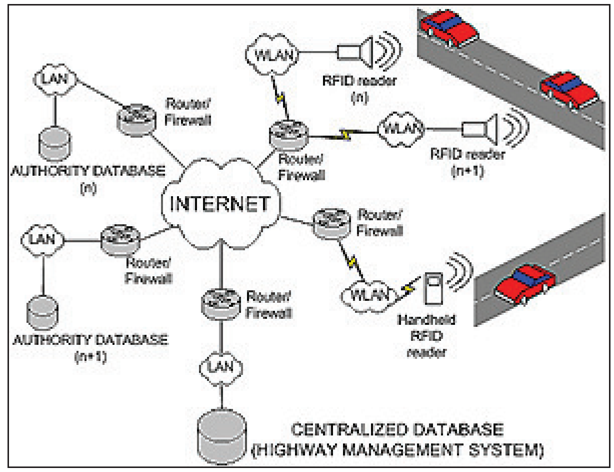

Figure 2: Schematic of the Ubiquitous Network

This architecture also guarantees a secured and reliable system for the local authority to access an HMS database and auto updating of the system. The technology can be pervasively deployed and applied in mobile commerce [2].

4. Frequency Range For Operating RFID

RFID systems are capable of providing real-time object visibility with high accuracy enabling continuous identification and location of all items and thereby providing accurate real-time data management. The RFID system used in the present work is based on the high frequency (~13 MHz) because currently, only low frequency (~125 kHz) and high frequency ranges are licensed for RFID tags in Malaysia.

Table 1: Application for various RFID technologies

Characteristic	LF (~125kHz)	HF (~13MHz)	UHF (~900MHz)	Microwave (2.45 GHz)
Protocol Standards	Fragmented	ISO 15693	ISO 18000	ANSI
Reading Range	< 8"	< 8"	> 10 feet	> 2 feet
Data Transfer Rate	10 kbps	30 kbps	256 kbps	256 kbps
Adhesive Labels	X	√	√	√
Interference	Motors	-	Cell Phones	WLAN

Low frequency (125 kHz), high frequency (13.56 MHz), and microwave frequency (2.45 GHz) technologies are currently available for RFID throughout the world but at different power levels and bandwidth. In Malaysia, the UHF range is dominantly used for cell phone industry. Unfortunately the UHF technologies can operate at nearby frequencies but with vastly different performance levels.

As cellular telephony (3G) moves towards higher frequencies of operation, international regulatory will find it easier to align RFID spectrum in the UHF frequency band [4].

Due to that demand, Malaysian Communication and Multimedia Commission (MCMC) has published their Standard Radio System Plan (SRSP) for the requirements of RFID operating frequency band which is from 919 MHz to 923 MHz. The channeling plan for RFID has been designed and discussed by the MCMC in that SRSP. The minimum bandwidth proposed for RFID usage is 1 MHz which is 5 x 200 kHz or 2 x 500 kHz [7].

This SRSP is valid after 3 months from the date of issue. The expected date for UHF operation of RFID in Malaysia is the end of January 2006. The frequency range currently available for RFID throughout the world but at different power levels and bandwidths [4] is summarized in Table 2.

Table 2: Frequency allocations worldwide for RFID

Frequency	Un-licensed Operation
125 kHz	World-Wide Allocation
13.56 MHz	World-Wide Allocation
458 MHz	Singapore, U.K, Hong Kong (500 mW/45 kHz)
865 MHz to 859 MHz	**Under Development for SRDs in Europe CEPT/ERC/REC 70-03 E** (500 mW/250 kHz now – 2W request for 866.6 MHz under review.)
902 MHz to 928 MHz	North and South America, Taiwan
918 MHz to 926 MHz	Australia, New Zealand, South Africa, China
2.45 GHz	World-Wide Allocation

5. The Networked Databases Communication

The scalable framework networked database architecture is basic structure for the ubiquitous RFID network.

Generally, this network architecture consists of a number of logically thin clients served by a single scalable database server, centralized HMS database. The client (local authority) can operate in, and switch between, both connected and disconnected mode seamlessly. The clients carry networked databases that contain a subset of data from the server. This database is managed by HMS Database Management System (HMS DBMS). Both applications and data are transparently downloaded into the client's (local authority) database a priori so that it uses less of the available bandwidth during operation [6].

To support more users without degrading the response time, more physical servers at the centralized HMS database can be added while the system is operating. Thus the scalable HMS database server supports scalability without downtime and virtually no administrative overhead.

The scalable HMS database server is responsible for providing high availability and scalable access to data and application databases.

6. Discussion

From the analysis shown above, five usefulness items can be identified which are detailed below:

1) Cost: RFID tags are still considered costly for pervasive infrastructure deployment and full scale security and identification as well as tag replacement within retail point-of-scale [4]. This technology currently offers a cost effective HMS. Further deployment within retail will encourage new applications.

2) Complete Integrated Transport Database: The deployment of RFID system in the HMS will bring into being an integrated transport database in Malaysia. Imperative information can easily be shared and retrieved by the local authorities for their comprehensive integrated transport databases. The backbone that supports this Integrated Transport Database is the networked database for RFID architecture.

3) Accident Statistical Analysis: When all the vehicles in Malaysia tagged by RFID, the authority can easily carry out the statistical analysis and derive appropriate solutions. The accident scene investigation will benefit from the detailed data stored in the centralized HMS database. A record of the average speed of the vehicle, identification, and the time and location will exist at the last reader. Witnesses who were passing scene at the particular time and location will also be identified. The stored data can produce a complete accident analysis. This analysis helps the authorities to study ways and methods of reducing the number of accidents.

4) Communication Performance: Communication performance of the RFID reader depends on the reliability of the network structure, which must be maintained until the reading of the tag is stored in the database of the HMS. Reliable communication between local authorities is also necessary for the exchange, sharing and updating of information, which is carried out through the structured RFID networked.

5) Integration with existing system: The RFID approach is capable of being integrated with the existing HMS application. Basically, the RFID reader is only added in the HMS as a part of the input system of sensors. The RFID reader identifies the information of the RFID tag. The captured input information is then stored in the existing database of HMS. The integration part will be to analyze and process the stored data.

6. Conclusions

The implementation of this approach to HMS may result in revolutionizing the management of the Malaysian transport statistical data. This data can help in planning the highway system of the country, in reducing the number of accidents on highways, and in traffic management. However, to integrate the management of the databases among the local authorities is a challenge that requires a lot of effort. The design of a secure sharing database and protocol must be integrated with the existing system. The issues of the integration require collaboration with the authorities that are concerned with managing the databases and need to be discussed further at higher levels.

Further work can be focused on the study of integration with GPS or Global Information System (GIS). Other recognition systems may benefit in terms of efficient management, maintenance and reduced operational cost.

The legal issues and privacy laws relating to the monitoring of drivers all the time may cause a major public concern. Such study would need to address, and discuss in details subjects regarding the issues of the civil rights and personal freedom, and whether it is morally acceptable to implement RFID in an open manner or be it restricted to specific legally defined applications.

MCMC also have to consider in advance the potential development of RFID applications. One of the issues that need to be focused on is the utilization and license control of UHF bandwidth for RFID. The UHF range for RFID application can enhance the reading range for RFID tag reading capability. By improving this capability, the development of RFID usage in Malaysia will rapidly grow. This advancement may to the invention of more RFID systems and applications, as the cost of the technology gets lower with the expected mass production.

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